Cold Silicon Detectors for COMPASS ◊

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In the COMPASS experiment, double-sided silicon strip detectors perform high precision tracking in the beam telescope and, when required by the physics programme, also downstream of the target. In the hadron beam times 2008 and 2009, reactions of a hadron beam scattering off protons under extremely small angles (e.g. central production) are under investigation, requiring very high tracking resolution around the target, which is achieved by the setup of three silicon stations upstream of the target, and two downstream of it, as depicted in Fig. 1. Each station houses two detector modules and measures, by mounting them with a stereo angle of 5°, 4 projections of the particle trajectories.

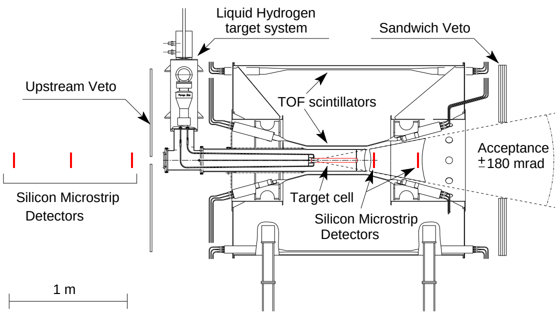

Fig. 1: Target region in the COMPASS hadron setup, with beam direction from the left. Three silicon stations define the incoming beam, while two stations in a specially-shaped conical cryostat (developped and built by the University of Torino) measure the outgoing particle trajectories. A peculiar challenge was the integration of their infrastructure in the space beween the components of the inner TOF scintillator system.

At very high particle fluxes, radiation damage deteriorates the performance of silicon detectors, particularly in the case of hadron beams. For the COMPASS physics programme with hadron beams a total integrated flux of 10^{13} particles per cm^2 per year is reached, while the maximum tolerable dose for silicons is stated to be about 10^{13} 1 MeV-neutron-equivalent-particles per cm^2. For the hadron beam time 2009, the radiation hardness of all detectors will be extended by cooling the silicon to a temperature of 200 K with liquid nitrogen.

Fig. 2: Photograph of a fully equipped cryogenic beam station. The phase separator and one detector module are visible. The silicon wafer is glued between two L-shaped PCBs, holding the APV readout chips and the pitch adapters, which are visible here for the side with 1280 strips read out by 10 APVs.

The liquid nitrogen is flushed through a thin capillary, connected close to the silicon wafer on the printed circuit board (PCB) and conforming to a minimum material budget of the detector setups, located in the acceptance of the spectrometer. Several modifications compared to the initial development have been introduced in order to reduce the thermal stress between the wafer and the PCB, as illustrated also in Fig. 2: T-like cuts segment the PCB where the capillary and the wafer are connected, and where the PCB is coldest. The wafer is glued only on the two readout sides. The capillary is bent in a meander-like shape, enhancing in addition the thermal contact.

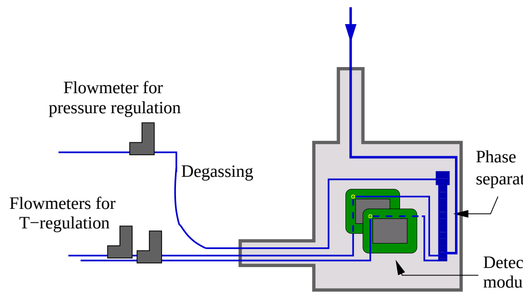

Fig. 3: Flow scheme near the detector modules in a beam station.

A constant flow of liquid nitrogen requires degassing at several stages on the way from the supply dewar in front of the experimental hall to the detector stations. The design of the distribution box, housing valves that allow the remote control of the detector cooling, has been modified such that a 100 ℓ buffer volume is included. Close to the detectors, regulated phase separators have been developed in such small shape, that it is possible to include them in the same shielding vacuum as the detectors themselves, as indicated in Fig. 3. The temperature on the detectors is stabilized by regulating the outgoing gas flux, which is achieved by a Siemens PLC.

The first beam station (shown in Fig. 2) was successfully tested at 200 K for more than one week in its final environment in the COMPASS spectrometer after the shortened 2008 beam time. The temperatures of the silicon wafers showed variations of less than 1 K. The cold readout electronics also operated stably. Several days of data taking with a cosmics trigger showed a clear Landau-distributed signal of the cosmic particles (see Fig. 4).

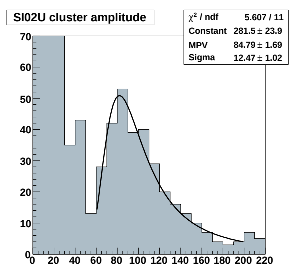

Fig. 4: Signal of cosmic particles

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